Author reply to Referee comments from **Referee # 1 Tariq Munir** from 21 February 2021 (https://doi.org/10.5194/bg-2020-440-RC1) on:

Cushion bog plant community responses to passive warming in southern Patagonia

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Reviewer comments (RC)
Author comments (AC)
Mentioned line numbers refer to the originally submitted manuscript
Manuscript changes (MC)

General comments: Climate warming has been frequently reported to occur under future climate change scenarios; therefore, it is very important and interesting to evaluate the impacts of it on various ecosystems – specifically those with significant accumulations of peat following a long-term carbon sink functioning since Holocene. One of the most important carbon sink ecosystems with peat accumulation is peatland – could be various kinds. Thus, this study of investigating carbon flux responses to expected warming in a cushion bog is important and interesting and may help advise ecosystem management and related policy development. This manuscript merits consideration for publication once the reviewer's comments are appropriately addressed to improve the quality of this rigorous research.

Specific comments: The abstract section is quite comprehensive and written with great clarity and brevity. The reader can feel the weakness of the study at line 6 where passive warming is shown to be only 0.4-0.7 with a very small n=3. No SD or SE is provided. For example, the uncertainty may be larger than the warming itself, and then what would be the strength of this study – not sure. But let me see ahead in the results. Additionally, it is amazing to find that small temperature increases of 0.4- 0.7 switched the system to a large increase in respiration and/or 55-85% decreases in CO2-C sequestration (sink to source).

We realize that in all its brevity the abstract can also be misunderstood. The reported range refers to the average difference between warmed plot and control plot at three replicates. We decided to report the range because we do not think it is very informative to calculate the standard deviation/error of three values. We dedicate sections in the results and discussion parts to characterize the temperature time series in more detail and apply statistical methods to investigate if the observed temperature differences at the three replicate plots could also be the result of random noise (which they are not at high significance levels).

We replaced "(n=3)" in the abstract with:

(At the three of ten treatment plots which were equipped with temperature sensors)

Line 43-45: It is noticeable that authors referred to old experimental warming research works conducted in 1997 and 2009 with chambers, and more recent works are ignored

here (One of the references is a review (Aronson and McNulty, 2009), not an experiment; however, it works well here). For example, Lyons et al. 2020 (Journal of Vegetation Science), Strack et al. 2019 (Ecohydrology), Yang et al. 2017 (Atmospheric Environment), Munir et al. 2017 (Ecohydrology). Also, the last paragraph of this manuscript describes how the chamber used in this study works, while this should be a separate comprehensive paragraph with more and recent reviews in the methods section.

At this stage of the manuscript (the end of the introduction), we only mention the method while we indeed address the experimental setup in more detail in subsection 2.2 “Setup of warming experiment” in the methods section.

We incorporated the newly suggested references and changed the paragraph from line 38 to 45 to:

To partly simulate future conditions, warming studies have commonly been conducted. Passive methods to manipulate soil and air temperatures have been chosen in studies focusing on high latitude peatlands (Laine et al., 2019; Lyons et al., 2020; Mäkiranta et al., 2017; Munir et al., 2017; Strack et al., 2019; Zaller et al., 2009) as these methods are cost-effective and appropriate for remote sites with limited power supply. Passive warming devices like open top chambers (OTCs) act as "solar energy traps" (Marion et al., 1997) primarily by reducing radiative heat loss (Aronson and McNulty, 2009). We conducted a field experiment to determine how cushion- forming plants respond to moderate experimental warming. We manipulated the temperature conditions passively with open side chambers (OSCs) similar to the ITEX Corners presented by Marion et al. (1997).

Line 113: Again, more recent references could be added here for readers to gain knowledge breadth.

More references added, see above.

Line 114: I am worried about how authors adjusted the volume of the chamber when the chamber was placed on the collar with protruding vascular vegetation which certainly occupied some volume of the chamber headspace and should be adjusted while applying PV=nRT in the respective excel column/empirical modelling – not just the coverage. Did authors adjust the transmittance in their chamber flux calculations? Additionally, this experiment used open side chambers for passive warming – what happened to rainfall or precipitation inputs compared to the control plots is not even briefly mentioned. Mention clearly if the chamber was open on top as well.

The vegetation establishes a dense cover, 2 to 3 cm above the soil surface, as shown in Figure 2. We estimated the chamber headspace individually for each plot a by taking into account surface irregularities as well as vegetation and collar height. PAR during measurements was measured inside the chamber. As clarified before, the device had an open-top design and its opening was facing north. We did not measure precipitation inside the plots, however, the water table (see Tables S3 to S5 in supplementary material) was near the surface throughout the vegetation periods guaranteeing plant water supply. We added in line 55:

Cushion-forming plants establish a very dense and low (about 2 to 3 cm above the soil surface) vegetation canopy (Figure 2).

In line 115, we added:

We estimated the head space, considering the distance from the vegetation to the border of the collar plus the height of the chamber above the collar.

Also, we added “internally” in line 117:

The chamber was internally equipped with…

Line 122: describe IRGA (make, model, location).

Which IRGA was used is specified in line 118.

Line 143-146: I appreciate that the authors used linear regression; an increase in CO2 concentration in the chamber headspace should be linear if the chamber volume is large and is corrected for inside temperature and pressure following ideal gas law. I see the measurement chamber size is very small (0.12 m2 basal area x 0.4 m height) compared to the contemporary research works that used passive warming with open top or side chamber – I know measurement time is somewhat smaller in this research. Also, covering the in-situ soil and vegetation has been frequently reported to manipulate the spontaneous CO2 fluxes across the soil-vegetation-air continuum (Hanson et al., 1993; Davidson et al., 2002; Denmead and Reicosky, 2003; Kutzbach et al., 2007) – did authors made any adjustments to mitigate these effects or interferences?

Actually the gas flux chamber we used was rather large. It is for example more than ten times larger in volume compared to commercially available systems offered by Licor Biosciences (https://www.licor.com/env/products/soil_flux/specs-chambers.html). The combination of a large volume and a short closure time (less than 50 seconds on average, see Figure A1) resulted in near linear concentration increases. Adjustments made to counteract disturbances and interferences of the gas flux caused by measuring it include: 1) usage of a large chamber, 2) a short chamber closure time, 3) removal of initial pertubations prior to flux calculation.

I think the statistical analysis section is missing – I need to know what design of experiment authors used, did they applied repeated measures with a mixed model or what statistical analysis techniques were used.

Since CO2 fluxes are highly dynamic due to their radiation dependence, we decided to compare average data-derived response functions (Equation 4) and not control and treatment fluxes (or their means) directly. Our sampling concept was to try to measure fluxes at the treatment and control plots during a wide range of light and temperature conditions in order to be able to estimate the parameters of the response functions for the different plot types as accurately as possible. As the main (non-linear) drivers of net CO2 flux are assumed to be known in this approach and are implemented in the response function, we did not apply any method to identify flux drivers like mixed linear models.

Line 187: SD?

See our reply to the comment to the abstract. In our opinion the range of the three values is more informative than reporting a standard deviation.

Line 194: what is $p<0.1$?

P-value of the Mann-Whitney U test as described in preceding sentence.

Fig. 3: axes labels are very small fonts.

Font size increased

Fig. 7. Why can't the y-axis have the label "ecosystem respiration" instead to let the reader know what flux is this?

Ecosystem respiration is the process leading to CO2 flux; CO2 flux is the quantity, we think the label is correct. For clarity we changed it to: Respiration CO2 flux, µmol m-2 s-1

Fig. 9. It is unusual to see different flux measurement units used for CO2 measurement in a single experiment.

We chose this unit for easier comparability with literature values.

Discussion: Line 295 onwards: how did researchers exclude the effect of rainfall or precipitation – since rainfall is from the top, not sides. How did rainfall enter the experimental chamber area? If the top was also open, then why it was not described here. I feel the authors need to describe the warming chamber in more detail in the setup of the experiment section. The authors have included a full paragraph on the wind direction effect. Please add a wind direction diagram, for example, the wind rose in the methods section to substantiate your arguments in the discussion section. Adding this figure may substantially strengthen the authors' arguments. I know wind may not be in a single direction like northerly but could take other directions as well with varying speeds during a year. Line

The OSC has no cover, rainfall can enter, see Figure 2. Polar histograms describing the frequency of wind directions (Figures S33 and S34) are shown in the supplementary material and are referred to in the main text in this paragraph (lines 304 and 308).

355: space. I notice authors keep switching between CO2 and CO2-C, please be consistent.

It is useful to talk about CO2-carbon for comparison with literature values and with other components of the carbon cycle. Ecosystem carbon balances and long-term carbon accumulation rates of peatlands are commonly reported as carbon and not as CO2 balances (e.g. Yu et al., 2010; Loisel and Yu, 2013; Bunsen and Loisel, 2020).

Line 398: please provide the temperature range here in brackets.

The conclusions were completely restructured the temperature range is now also mentioned here. Also see our response to the comment of referee #2 to line 397.

Over the main growing season of two exemplary years, warmed A. pumila cushions cumulatively took up 55 % and 85 % less CO2-C than the cushions of unaltered control plots. This change in net C uptake is considerable, especially when comparing the amount of artificial warming achieved in our experiment (annual average between 0.4 °C and 0.7 °C at the three of ten replicates which were equipped with temperature sensors) with temperature projections for the region from the Coupled Model Intercomparison Project Phase 6 (CMIP6).

Line 404: replace treatment plots with warmed plots.

Done

Line 412-413: replace "the A. pumila cushions where temperature conditions were manipulated" with "warmed A. pumila cushions".

Done

Line 416: please do not mix manipulated warming and weather temperatures – be clear in conclusions. As authors used here >18C, they can use the passive warming values as well

to help the reader a take-home message with exact passive warming and their calculated or modelled effects on GPP and Respiration.

We suspect a misunderstanding here. What we want to say is: Warming alters plant properties and leads to a stronger temperature response of NEE from treated plants. As mentioned above, we rewrote the conclusions entirely.

Authors may want to provide passive warming average temperatures during study years/seasons at various plots in a separate table.

We do, see Appendix D.

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